

Combined Heat and Power (CHP) Practicum

Western Missouri CHP Summit:
Resiliency for Critical Infrastructure

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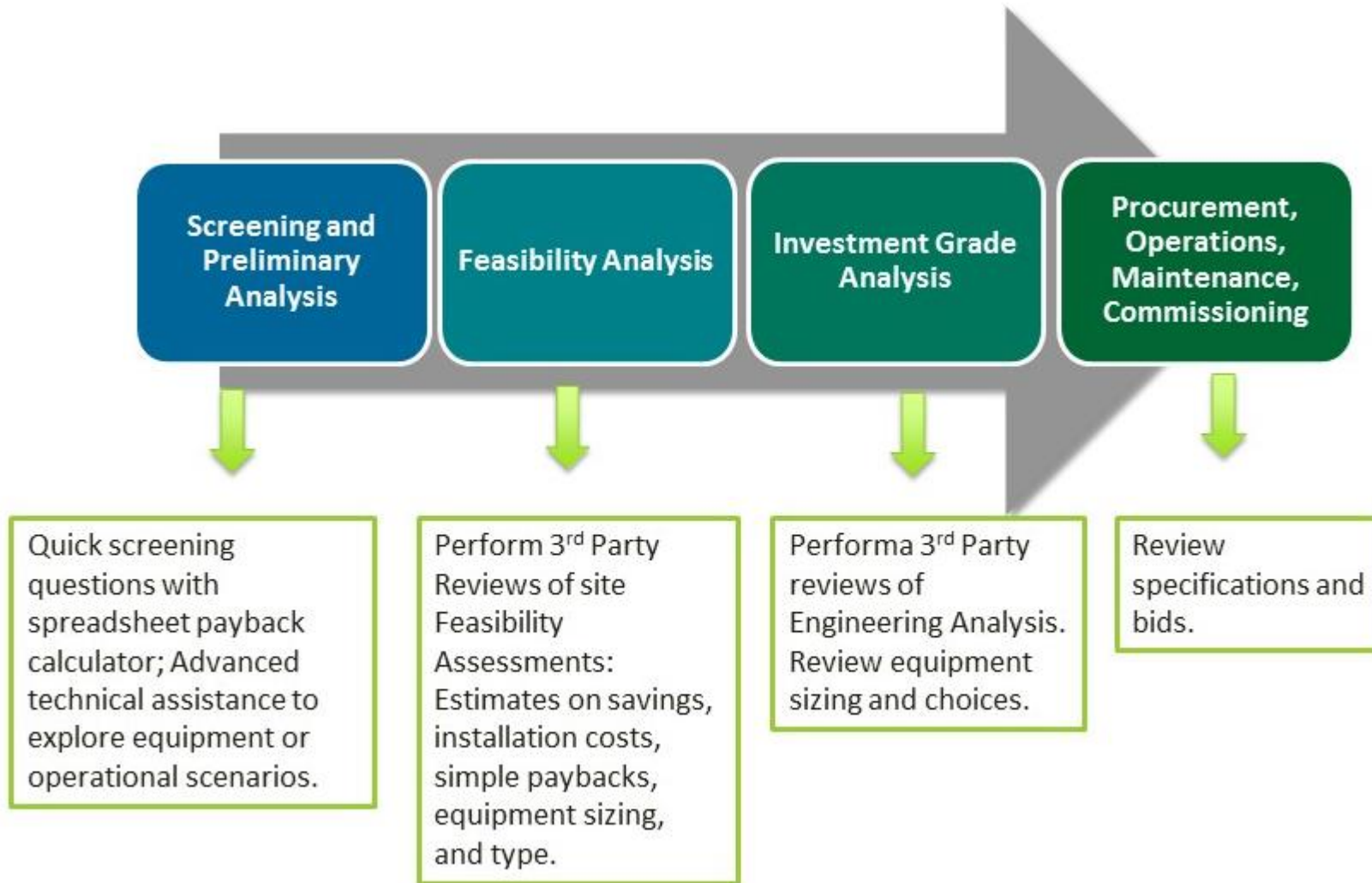


CHP Technical Assistance Partnerships
CENTRAL

Agenda

- What are the CHP TAPs?
- CHP Project Development Process
- CHP TAP Screening – Step-by-Step Walk-Through
- Additional Considerations that can Impact CHP Economics

CHP Project Development Flow Process and CHP TAP Technical Assistance



Overview of DOE TAP CHP Screening Analysis

- High level assessment to determine if site shows potential for a CHP project
 - Quantitative Analysis
 - Energy Consumption & Costs
 - Estimated Energy Savings & Payback
 - CHP System Sizing
 - Qualitative Analysis
 - Understanding project drivers
 - Understanding site peculiarities

Annual Energy Consumption		Base Case	CHP Case
Purchased Electricity, kWh		88,250,160	5,534,150
Generated Electricity, kWh		0	82,716,010
On-site Thermal, MMBtu		426,000	18,872
CHP Thermal, MMBtu		0	407,128
Boiler Fuel, MMBtu		532,500	23,590
CHP Fuel, MMBtu		0	969,845
Total Fuel, MMBtu		532,500	993,435
Annual Operating Costs			
Purchased Electricity, \$		\$7,060,013	\$1,104,460
Standby Power, \$		\$0	\$0
On-site Thermal Fuel, \$		\$3,195,000	\$141,539
CHP Fuel, \$		\$0	\$5,819,071
Incremental O&M, \$		\$0	\$744,444
Total Operating Costs, \$		\$10,255,013	\$7,809,514
Simple Payback			
Annual Operating Savings, \$			\$2,445,499
Total Installed Costs, \$/kW			\$1,400
Total Installed Costs, \$/k			\$12,990,000
Simple Payback, Years			5.3
Operating Costs to Generate			
Fuel Costs, \$/kWh			\$0.070
Thermal Credit, \$/kWh			(\$0.037)
Incremental O&M, \$/kWh			\$0.009
Total Operating Costs to Generate, \$/kWh			\$0.042

CHP TAP Qualification Screening Steps

(covered on subsequent slides)

1. Site Specific Information
2. Utility Costs
3. CHP System Specifications
4. Energy Consumption / CHP Operation
5. Annual Operating Costs
6. CHP System Economics
7. Operating Costs per kWh

Collected Data

- **12 months of utility data**
 - Blended cost of utilities
 - Thermal and electric demand of the facilities (average, peak, seasonal)
 - Annual natural gas and electricity consumption
- **Facility operating hours**
- **Existing equipment info**
 - Heating and cooling capacities, efficiency, age, etc.
- **Additional helpful info**
 - Resiliency needs, climate goals, utility contract ending

1. Site Specific Information

- **12 months of utility data**

- Thermal and electric demand of the facilities (average, peak, seasonal)
- Annual natural gas and electricity consumption

- **Facility operating hours**

DOE TAP CHP Screening Technical Assistance

Gas Fueled CHP - Recip Engine, Microturbine, Fuel Cell or Gas Turbine Systems / natural gas, LFG, biogas

Note: The results of this screening analysis use average values and assumptions and should not be utilized as an investment grade analysis.

Facility Information

Facility Name

Location (City, State)

Application

Hospital	
City	Missouri
500-600 Bed Hospital	
Date:	16-Oct-18

Loads

Site Operating Schedule

Annual Operating Hours of Site

Baseload Electric Demand, kW

Annual Site Electricity Consumption, kWh

Total Annual Thermal Demand, MMBtu/yr

Baseload Thermal Demand, MMBtu/hr

CHP Operating Schedule

Annual Hours of CHP Operation

Baseload Power Demand during CHP Operation, kW

Electricity Consumption during CHP Operation, kWh

Thermal Demand during CHP Operation, MMBtu/yr

CHP Baseload Thermal Demand, MMBtu/hr

Annual CHP Addressable Thermal Demand, MMBtu/yr

24/7
8,760
3,416
41,924,572
142,869
11.00
12 Months
8,760
3,416
41,924,572
142,869
11.00
142,869

Addressable Thermal Load (MMBtu/hr)

Winter Thermal	Shoulder Thermal	Summer Thermal
22.0	16.2	11.0
2,160	4,392	2,208

Avg Load

Hours

2. Utility Costs

- **12 months of utility data**
 - Electricity and natural gas
 - Blended costs of utilities
- **Avoided Rate / Standby Rate**
- **Existing equipment info**
 - Heating and cooling capacities, efficiency, age, etc.

Energy Costs	Base Case	CHP Case
Boiler/Thermal Fuel Costs, \$/MMBtu	\$4.20	\$4.20
CHP Fuel Costs, \$MM/Btu		\$4.20
Average Electricity Costs, \$/kWh	\$0.065	
Percent Average per kWh Electric Cost Avoided		90%
Standby Rate, \$/kW		
Excess Power Sales Price, \$/kWh		
Existing System		
Displaced Thermal Equipment Efficiency, %	83.0%	

Percent Average per kWh Electric Cost Avoided: Assesses how utility rates (i.e. fixed charges and standby rates) affect the blended rate savings (total kWh price for electricity) by comparing a customer's utility bills before and after a CHP installation. For example, an avoided rate of 100% means that one kWh generated onsite reduces the utility bill by the full blended cost of one kWh of purchased power. This is rarely the case in most tariff structures. This example incorporates an avoided rate of 90%, meaning one kWh of electricity generated from CHP reduces utility purchases by 90% of the blended rate prior to CHP.

3. CHP System Specs

- Initial sizing of CHP system
- Utilizes typical CHP performance operating and cost data from U.S. DOE CHP Technology Fact Sheets

CHP System

Sales of Excess Power (Yes/No)

Net CHP Power, kW

CHP Electric Efficiency, % (HHV)

CHP Thermal Output, Btu/kWh

CHP Thermal Output, MMBtu/hr

CHP Fuel

CHP Availability, %

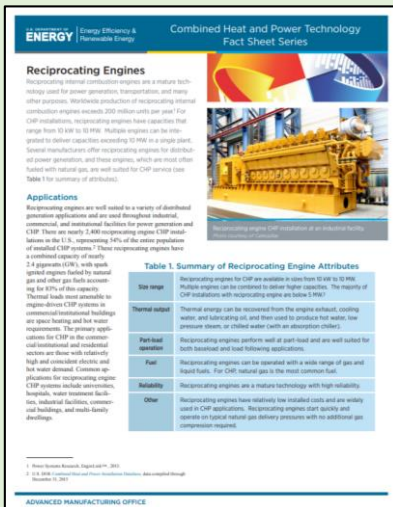
Incremental O&M Costs, \$/kWh

Thermal Utilization, %

Total Installed Costs, \$/kW

CHP Case 1

Sales of Excess Power (Yes/No)	No
Net CHP Power, kW	3,402
CHP Electric Efficiency, % (HHV)	40.9%
CHP Thermal Output, Btu/kWh	3,233
CHP Thermal Output, MMBtu/hr	11.00
CHP Fuel	Nat Gas
CHP Availability, %	98%
Incremental O&M Costs, \$/kWh	\$0.011
Thermal Utilization, %	100%
Total Installed Costs, \$/kW	\$1,800



(Fact Sheet:

<https://www.energy.gov/eere/amo/downloads/reciprocating-engines-doe-chp-technology-fact-sheet-series-fact-sheet-2016>)



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Comparison of CHP Characteristics for Typical Systems

Characteristic	Technology				
	Reciprocating Engine	Gas Turbine	Microturbine	Fuel Cell	Steam Turbine
Size Range	10 kW–10 MW	1 MW–300 MW	30 kW–330 kW (larger modular units available)	5 kW–2.8 MW (larger modular units available)	100 kW–250 MW
Electric Efficiency (HHV)	30–42%	24–36%	25–29%	38–42%	5–7%
Overall CHP Efficiency (HHV)	77–83%	65–71%	64–72%	62–75%	80%
Total Installed Cost (\$/kW) [3]	\$1,400–\$2,900	\$1,300–\$3,300	\$2,500–\$3,200	\$4,600–\$10,000	\$670–\$1,100 [4]
O&M Cost (¢/kWh)	0.9–2.4	0.9–1.3	0.8–1.6	3.6–4.5	0.6–1.0
Power to Heat Ratio	0.6–1.2	0.6–1.0	0.5–0.8	1.3–1.6	0.07–0.10
Thermal Output (Btu/kWh)	2,900–6,100	3,400–6,000	4,400–6,400	2,200–2,600	30,000–50,000
Fuel Pressure (psig) [5]	1–75	100–500 (may require fuel compressor)	50–140 (may require fuel compressor)	0.5–45	n/a
Part Load Efficiency	Good at both part-load and full-load	Better at full-load	Better at full-load	Better at full-load	Good at both part-load and full-load
Type of Thermal Output	LP steam, hot water, space heating, chilled water	LP-HP steam, hot water, process heating, chilled water	LP steam, hot water, chilled water	LP steam, hot water, chilled water	LP-HP steam, hot water, chilled water

4. Energy Consumption – CHP Operation

Annual Energy Consumption	Base Case	CHP Case	CHP Fuel Use Efficiency	
Purchased Electricity, kWh	41,924,572	12,719,082	29,205,490	CHP Electricity, kWh
Generated Electricity, kWh	0	29,205,490	99,649	MMBtu Electricity
Generated Electricity Used on Site, kWh	0	29,205,490	94,421	MMBtu Used Thermal
Generated Electricity Sold, kWh	0	0	243,641	MMBtu CHP Fuel
On-site Boiler/Heater Thermal, MMBtu/yr	142,869	48,447	79.7%	CHP Fuel Use Efficiency (HHV)
CHP Thermal Used, MMBtu/yr	0	94,421	1.06	Power to Heat Ratio
Boiler/Heater Fuel, MMBtu/yr	172,131	58,370		
CHP Fuel, MMBtu/yr	0	243,641		
Total Fuel, MMBtu/yr	172,131	302,011		

- Estimated annual energy performance is compared between the Base Case (no CHP) and the CHP Case (with CHP)
- CHP efficiencies and the Power-to-Heat Ratio are calculated

5. Annual Operating Costs/Savings

Annual Operating Costs	Base Case	CHP Case
Purchased Electricity	\$2,725,097	\$1,016,576
Standby Charges (Option 2)	\$0	\$0
On-site Boiler/Heater Fuel	\$722,950	\$245,155
CHP Fuel	\$0	\$1,023,292
Incremental O&M	\$0	\$321,260
Total Operating Costs	\$3,448,047	\$2,606,283
Excess Power Sales		\$0
Operating Savings		\$841,764

- Annual operating costs are compared between the Base Case (no CHP) and the CHP Case (with CHP)
- In this scenario, standby charges are accounted for in the purchased electricity in the terms of avoided costs

6. CHP System Economics

Simple Payback		CHP Case 1
CHP Installed Costs		\$6,123,600
Additional Costs		\$0
Federal Investment Tax Credit (Yes/No)	No	\$0
Avoided Equipment Credits*		\$0
Total Installed Costs with Equipment Credit		\$6,123,600
Value of Resiliency		\$0
Total Installed Costs less Incentives		\$6,123,600
Annual Operating Savings		\$841,764
Simple Payback, Years (w/o incentives)		7.3
Simple Payback, Years (with incentives)		7.3

- Simple payback is determined with typical CHP installed costs and operating savings
- A variety of factors can be incorporated to analyze the financial impacts on a potential CHP project (next section)

7. Operating Costs per kWh

Operating Costs to Generate	
Fuel Costs, \$/kWh	0.0350
Thermal Credit, \$/kWh	(\$0.0164)
Incremental O&M, \$/kWh	0.0110
Total Operating Costs to Generate, \$/kWh	\$0.030

- Operating costs are calculated to determine the costs to generate in terms of \$/kWh
- Fuel costs, thermal credit from offset boiler fuel, and incremental O&M are incorporated

Continuing the Analysis...

Factors to Consider that can Impact CHP Economics



- I. **Utility Costs (discounted natural gas costs)** – increased natural gas consumption may provide opportunity for discounted natural gas price
- II. **Utility Costs (lower/higher energy prices)** – impacts of current/future electric and/or natural gas prices can be reflected in sensitivity analyses
- III. **Redundancy (multiple generating units)** – multiple CHP units can provide redundancy and additional resiliency benefits, but typically with higher upfront costs
- IV. **Avoid Boiler Replacement** – apply credit to CHP installation costs from allocated funds of new boiler(s)
--- **Absorption Cooling** – an absorption chiller can utilize CHP thermal output during summer months and could provide an alternative option to new electric chillers (note: new absorption chiller not analyzed in this exercise due to existing absorption chiller)
- V. **Reducing Avoided Rate Percentage** – assessing how to reduce the utility rate impact through analyzing utility rate class impacts, energy consumption, system availability, scheduling of maintenance, etc.
- VI. **Avoided Installation of Diesel Backup Gensets** – apply credit to CHP costs from funds for backup gensets
- VII. **Value of Resiliency** – factor in monetary value of resiliency benefits
- VIII. **Federal Investment Tax Credit** – 10% investment tax credit (ITC)

I. Impact of Discounted Natural Gas Price

Energy Costs	Base Case	CHP Case 1	CHP Case 2
Boiler/Thermal Fuel Costs, \$/MMBtu	\$4.20	\$4.20	\$3.78
CHP Fuel Costs, \$MM/Btu		\$4.20	\$3.78
Average Electricity Costs, \$/kWh	\$0.065		
Percent Average per kWh Electric Cost Avoided		90%	90%
Standby Rate, \$/kW			
Excess Power Sales Price, \$/kWh			

- Increased natural gas consumption may provide opportunity for discounted natural gas price
- Annual savings increase from \$842K to \$969K
- Simple Payback reduces from **7.3 years to 6.3 years**

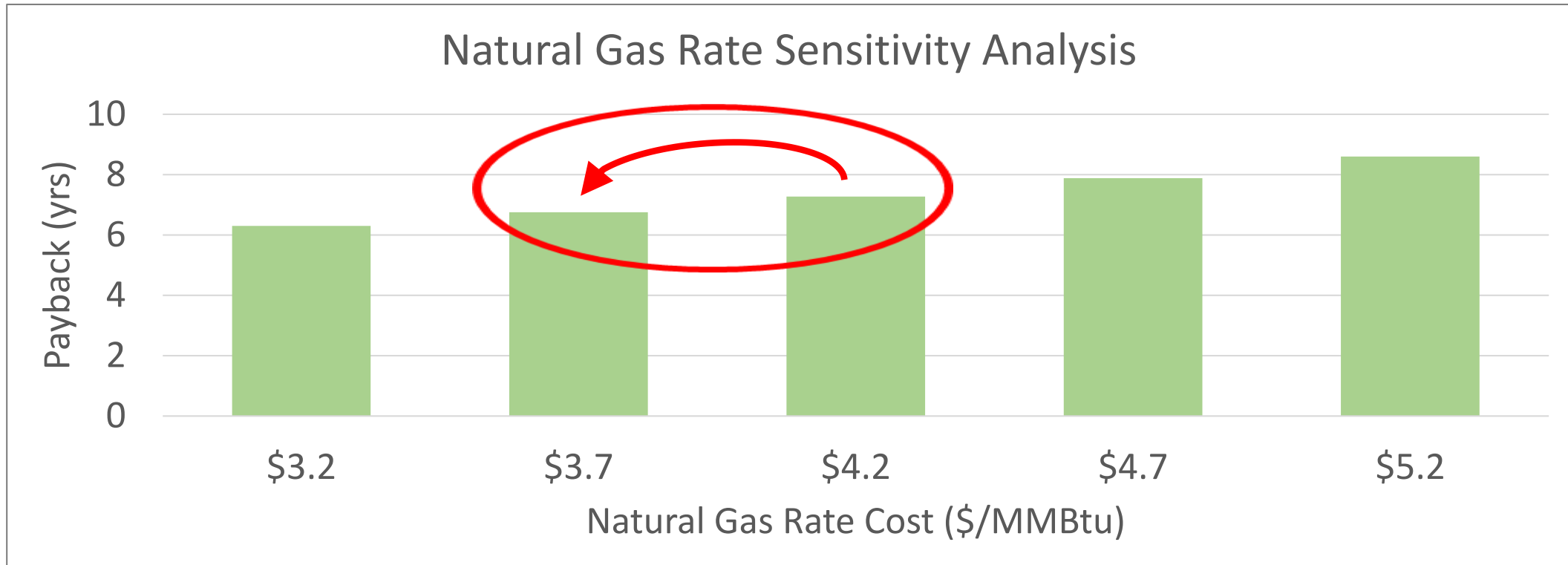
I. Impact of Discounted Natural Gas Price (cont.)

Simple Payback		CHP Case 1	CHP Case 2
CHP Installed Costs		\$6,123,600	\$6,123,600
Additional Costs		\$0	\$0
Federal Investment Tax Credit (Yes/No)	No	\$0	\$0
Avoided Equipment Credits*		\$0	\$0
Total Installed Costs with Equipment Credit		\$6,123,600	\$6,123,600
Value of Resiliency		\$0	\$0
Total Installed Costs less Incentives		\$6,123,600	\$6,123,600
Annual Operating Savings		\$841,764	\$968,608
Simple Payback, Years (w/o incentives)		7.3	6.3
Simple Payback, Years (with incentives)		7.3	6.3

- Decreased marginal rate due to increased natural gas consumption
- Annual savings increase from \$842K to \$969K
- Simple Payback reduces from **7.3 years to 6.3 years**

II. Utility Rates – Sensitivity Analyses

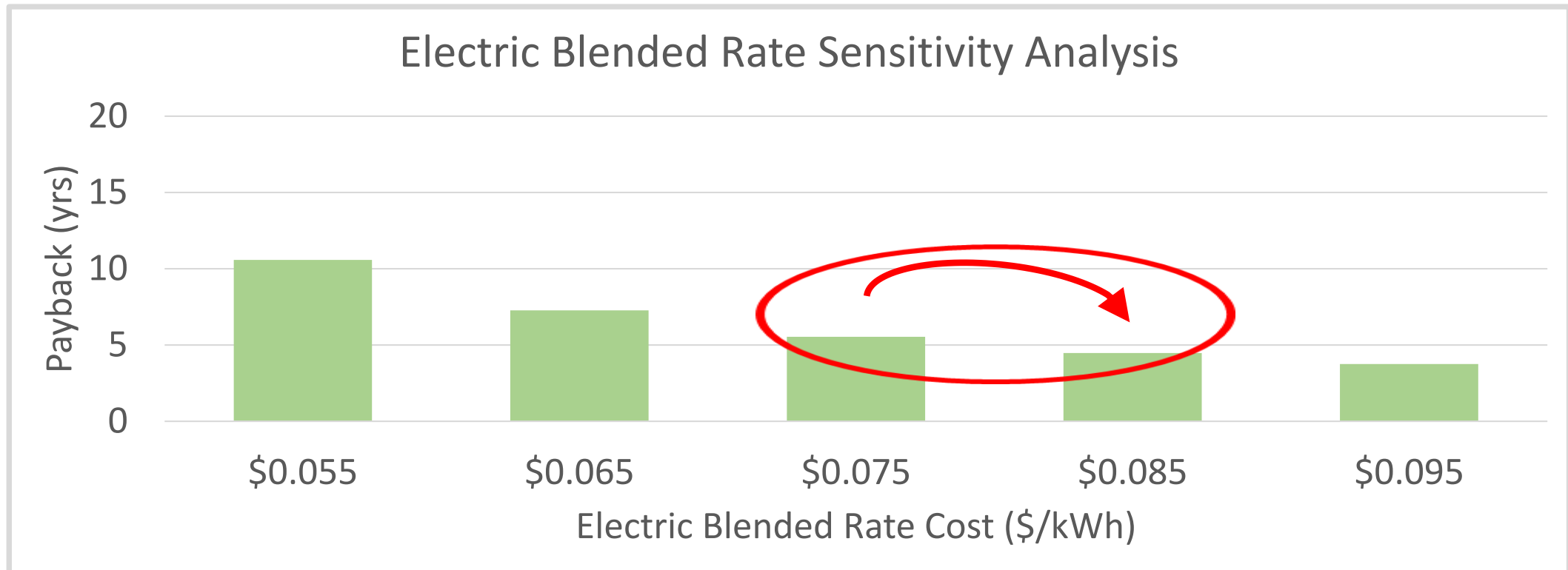
Impact of Natural Gas Rate Increases/Decreases



- Natural gas prices (current/future) can impact economics of a CHP project
- With a 10% (\$0.42/MMBtu) decreased price of natural gas (both in the Base Case and CHP Case), the simple payback reduces from **7.3 years to 6.8 years**

II. Utility Rates – Sensitivity Analyses (cont.)

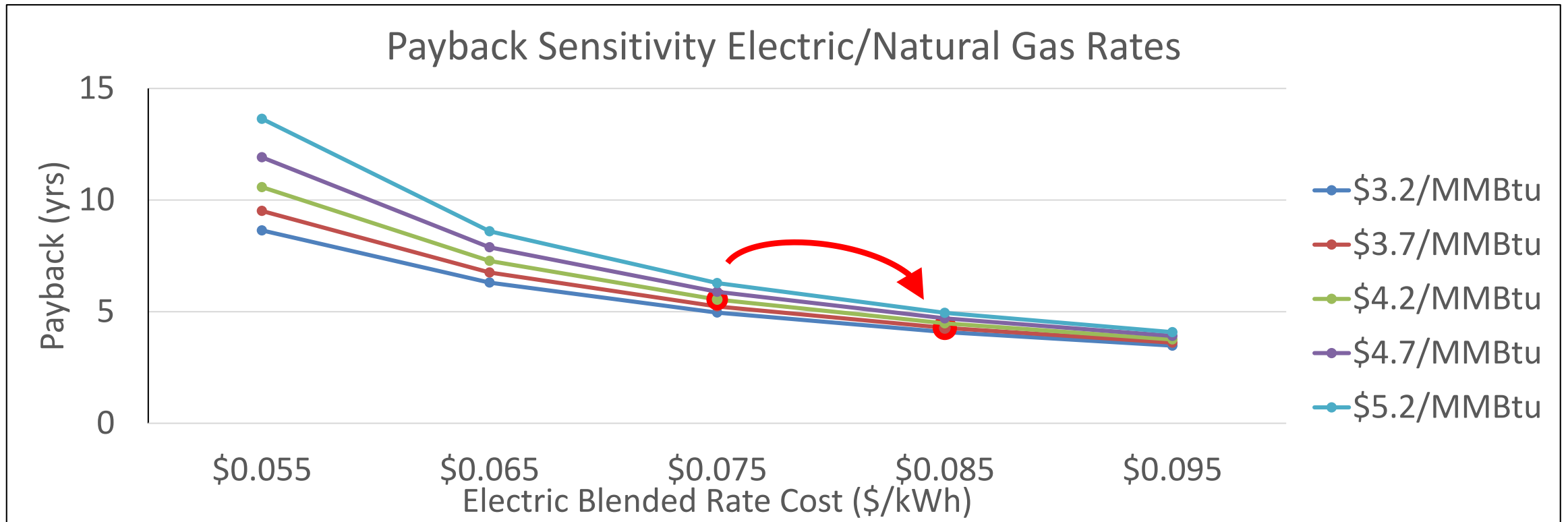
Impact of Electricity Rate Increases/Decreases



- Natural gas prices (current/future) can impact economics of a CHP project
- With a 15% (1¢/kWh) rate increase in the price of electricity (both in the Base Case and CHP Case), the simple payback reduces from **7.3 years to 5.5 years**

II. Utility Rates – Sensitivity Analyses (cont.)

Impact of Combined Energy Price Increases/Decreases



- Combined impact of natural gas and electric prices should be analyzed
- With a 10% (\$0.42/MMBtu) decrease in the natural gas price and a 15% (1¢/kWh) rate increase in the price of electricity, the simple payback reduces from **7.3 years to 5.2 years**

III. Redundancy (multiple generating units)

CHP System	CHP Case 1	CHP Case 2	2 x 1,700 kW Engines
Sales of Excess Power (Yes/No)	No	No	
Net CHP Power, kW	3,402	3,402	
CHP Electric Efficiency, % (HHV)	40.9%	37.5%	
CHP Thermal Output, Btu/kWh	3,233	3,979	
CHP Thermal Output, MMBtu/hr	11.00	13.54	
CHP Fuel	Nat Gas	Nat Gas	
CHP Availability, %	98%	98%	
Incremental O&M Costs, \$/kWh	\$0.011	\$0.015	
Thermal Utilization, %	100%	100%	
Total Installed Costs, \$/kW	\$1,800	\$2,300	

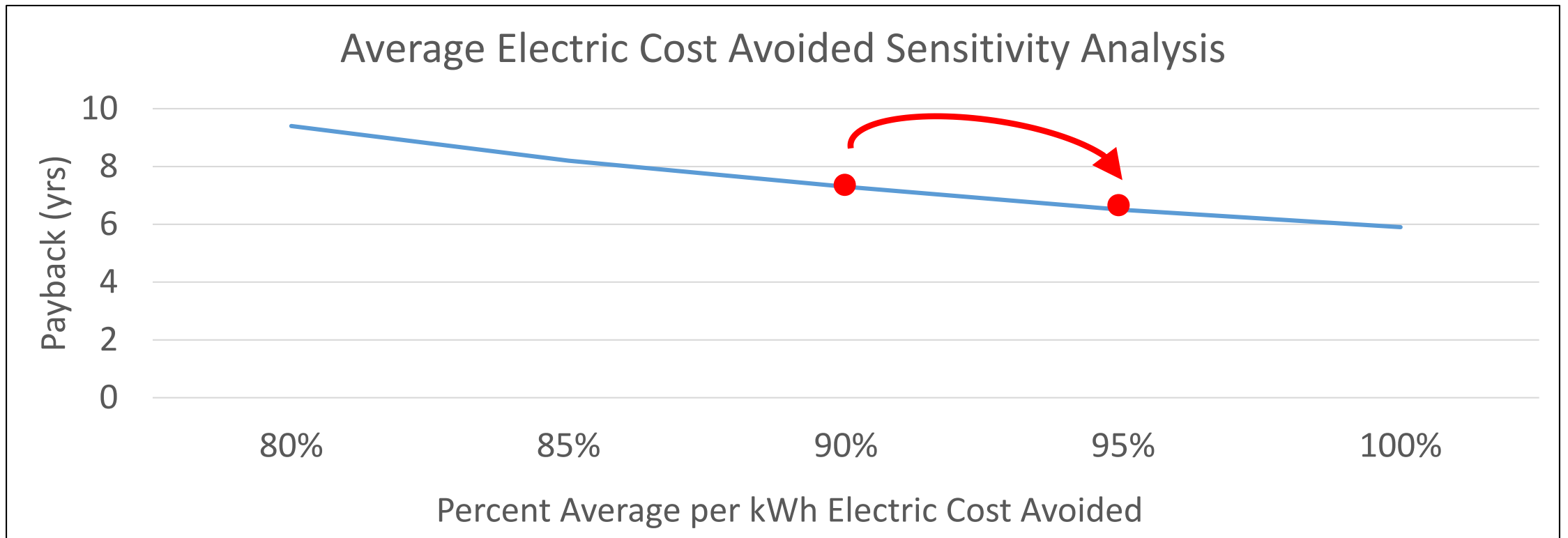
- Installing multiple generating units provides redundancy and increases resiliency benefits
 - Maintenance can be staggered for multiple generating units
 - Unplanned outage may only affect one unit while second unit can maintain operation
- Simple Payback increases from **7.3 years to 11 years**

IV. Avoided Boiler Replacement Costs

Simple Payback		CHP Case 1	CHP Case 2
CHP Installed Costs		\$6,123,600	\$6,123,600
Additional Costs		\$0	\$0
Federal Investment Tax Credit (Yes/No)	No	\$0	\$0
Avoided Equipment Credits*	\$240,110	\$0	(\$240,110)
Total Installed Costs with Equipment Credit		\$6,123,600	\$5,883,490
Value of Resiliency		\$0	\$0
Total Installed Costs less Incentives		\$6,123,600	\$5,883,490
Annual Operating Savings		\$841,764	\$841,764
Simple Payback, Years (w/o incentives)		7.3	7.0
Simple Payback, Years (with incentives)		7.3	7.0

- CHP can offset the need for a facility to purchase new boiler equipment
- For this example, the CHP system can provide 11 MMBtu/hr offsetting the cost of purchasing a boiler of equivalent size (source: boiler cost from previous study)
- Total Installed Costs reduced from \$6.1M to \$5.9M
- Simple Payback reduces from **7.3 years to 7.0 years**

V. Percent Average per kWh Electric Cost Avoided



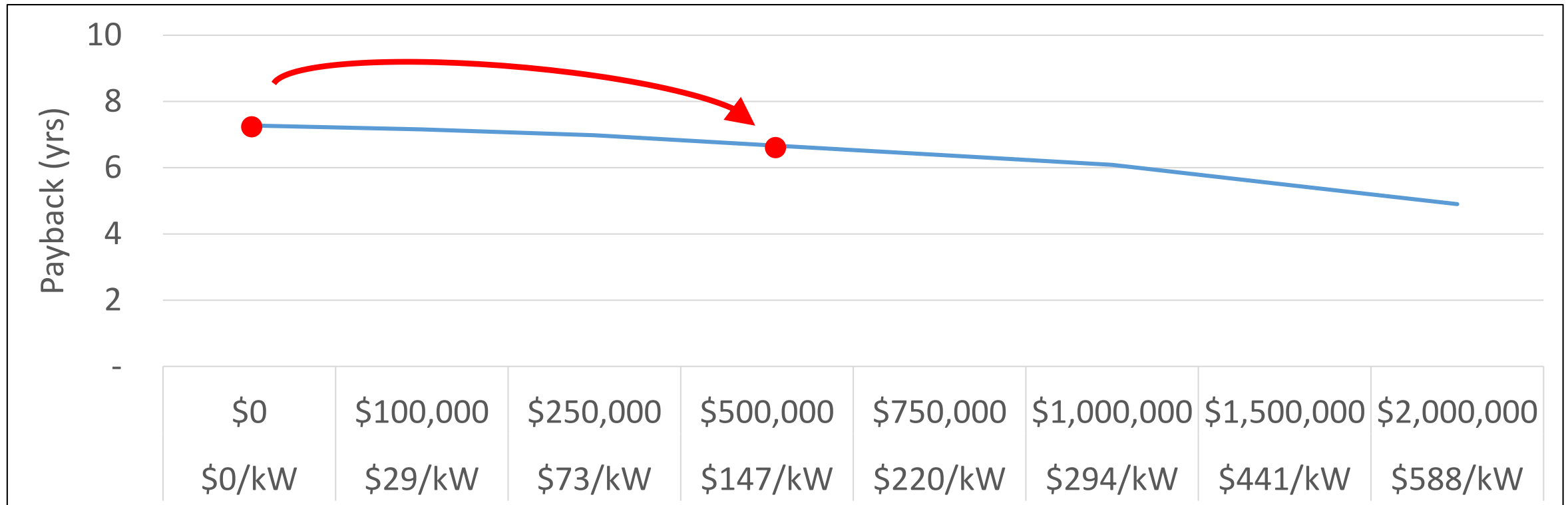
- Assessing how to reduce the utility rate impact through analyzing utility rate class impacts, energy consumption, system availability, scheduling of maintenance, etc.
- With a 5% increase in avoided cost percentage of kWh, the simple payback reduces from **7.3 years to 6.5 years**

VI. Avoided Installation Credit of Diesel Backup Gensets

Simple Payback		CHP Case 1	CHP Case 2
CHP Installed Costs		\$6,123,600	\$6,123,600
Additional Costs		\$0	\$0
Federal Investment Tax Credit (Yes/No)	No	\$0	\$0
Avoided Equipment Credits*	\$714,000	\$0	(\$714,000)
Total Installed Costs with Equipment Credit		\$6,123,600	\$5,409,600
Value of Resiliency		\$0	\$0
Total Installed Costs less Incentives		\$6,123,600	\$5,409,600
Annual Operating Savings		\$841,764	\$841,764
Simple Payback, Years (w/o incentives)		7.3	6.4
Simple Payback, Years (with incentives)		7.3	6.4

- CHP can offset the need for a facility to purchase backup diesel generator sets
- For this example, 3.4 MW of backup diesel gensets are avoided due to the 3.4 MW CHP System (calculated at an installed cost of \$/kW analyzing 500 kW units, Source: RS Means 2015)
- Total Installed Costs reduced from \$6.1M to \$5.4M
- Simple Payback reduces from **7.3 years to 6.4 years**

VII. Impact of Value of Resiliency



- Value of resiliency can impact CHP economics (value determined on case-by-case basis)
- For an example resiliency value of ~\$150/kW (i.e. \$500K), the Simple Payback reduces from **7.3 years to 6.7 years**

VIII. Impact of 10% Federal Investment Tax Credit

Simple Payback		CHP Case 1	CHP Case 2
CHP Installed Costs		\$6,123,600	\$6,123,600
Additional Costs		\$0	\$0
Federal Investment Tax Credit (Yes/No)	Yes	\$0	(\$612,360)
Avoided Equipment Credits*		\$0	\$0
Total Installed Costs with Equipment Credit		\$6,123,600	\$5,511,240
Value of Resiliency		\$0	\$0
Total Installed Costs less Incentives		\$6,123,600	\$5,511,240
Annual Operating Savings		\$841,764	\$841,764
Simple Payback, Years (w/o incentives)		7.3	6.5
Simple Payback, Years (with incentives)		7.3	6.5

- A federal investment tax credit (ITC) of 10% is available for a for-profit organization and/or a 3rd party owned/operated CHP system
- Total Installed Costs reduced from \$6.1M To \$5.5M
- Simple Payback reduces from **7.3 years to 6.5 years**

Factoring All Considerations

(Initial Simple Payback of 7.3 years... when All Factors Applied, Resulting Simple Payback is 2.9 years)

#	Impacting Factor	Individual Measure Impact on Simple Payback (years)	Cumulative Measure Impact on Simple Payback (years)
1	Discounted Natural Gas Rate of 10% (CHP Case Only)	6.3 years	6.3 years
2a	Decreased Natural Gas Price of 10% (both in Base Case and CHP Case)	6.8 years	6.1 years
2b	Increased Electric Price of 15% (in both Base Case and CHP Case)	5.5 years	4.8 years
3	Redundancy (multiple CHP units)	11 years	Not Included
4	Avoided Boiler Replacement Credit	7.0 years	4.6 years
5	Avoided Rate Percentage Increase of 5%	6.5 years	4.3 years
6	Avoided Installation Credit of Diesel Backup Emergency Genset	6.4 years	3.7 years
7	Adding Value of Resiliency (~\$150/kW or ~\$500K)	6.7 years	3.4 years
8	10% Federal Investment Tax Credit	6.5 years	2.9 years

Typical Next Steps Following CHP Qualification Screening by the CHP TAP

- Following a qualification screening review with a client, the US DOE CHP TAP can provide advanced technical assistance to address site specific criteria
- If the analysis shows favorable potential, the site is recommended to move forward with a feasibility study
- The CHP TAP is available to provide no-cost, unbiased 3rd party reviews on behalf of the clients moving forward for all stages of implementing combined heat and power

Summary

- Collecting data and implementing a screening analysis are the first steps towards evaluating the initial economics of a CHP project
- Emerging drivers are creating new opportunities to evaluate CHP
- Factors in addition to spark spread need to be accounted for and can significantly impact the economics of a potential CHP project
- Resources are available through the US DOE CHP TAP to discuss CHP project opportunities and to receive technical assistance

Next Steps

- Contact the US DOE CHP TAP:
 - To receive a complementary CHP qualification screening or other technical assistance
 - If you already have an existing CHP plant and interested in expanding it
 - If you need an unbiased 3rd Party Review of a proposal

Thank You

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